

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) Publication number:

0 681 787 A2

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 95106817.0

(51) Int. Cl.⁶: **A23K 1/165, A61K 38/46**

(22) Date of filing: 05.05.95

(30) Priority: 10.05.94 GB 9409336

(43) Date of publication of application:
15.11.95 Bulletin 95/46(84) Designated Contracting States:
BE CH DE DK ES FR GB IE IT LI NL SE

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(54) Use of an enzyme for manufacturing an agent for the treatment and/or prophylaxis of coccidiosis.

(57) The present invention provides the use of a carbohydrase and/or a protease for the manufacture of an agent for the treatment and/or prophylaxis of coccidiosis. The agent can be in the form of a cereal-based animal feed. The carbohydrase may be a polysaccharidase such as a xylanase or a cellulase e.g. β -glucanase. The agent may optionally include conventional non-enzymic anticoccidial agents.

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The present invention relates to the use of certain enzymes for the manufacture of an agent for the treatment and/or prophylaxis of coccidiosis.

Coccidiosis is a common cause of disease in intensively-reared farm livestock, particularly in poultry. Coccidiosis is caused by a protozoa, a single-celled parasite, of the subphylum *Apicomplexa*. Many of the species that cause the disease in domestic animals belong to the genus *Eimeria*. The parasites multiply in the epithelium of the intestine. In chickens, seven species of *Eimeria* have been described, five of which are considered to be pathogenic. These are *E. acervulina*, *E. maxima*, *E. necatrix*, *E. tenella* and *E. brunetti*.

Coccidia are ubiquitous organisms and are generally endemic wherever chickens are raised. Outbreaks of disease can vary from severe to very mild infections. Like many parasitic protozoa, the life cycle of the *Eimeria* is relatively complex. Sexual and asexual multiplication occurs within the chickens' intestines. During this process of multiplication and development of the parasite, the host tissue is destroyed which leads to the various clinical manifestations observed in outbreaks of coccidiosis. The oocysts produced and excreted develop further outside the host where they may undergo further development and infect other chickens. Oocysts can in fact survive outside the host for a long period of time which enables them to infect subsequent crops of birds. They may also be spread between flocks by other agents including people, pets, insects, rodents, dust and other birds.

Sporulated oocysts contain four sporocysts, each containing two sporozoites. These sporozoites are released by mechanical and enzymatical action in the digestive tract of the chicken. This enables them to invade the epithelial cells in the intestine or caeca depending on the *Eimeria* species involved.

Although there are differences in pathogenicity between species and strains of *Eimeria*, the overall symptoms may be one or more of the following: bloody droppings, high mortality, general lethargy, emaciation, a marked drop in feed consumption, diarrhoea and a drop in egg production. It has been estimated that coccidiosis is probably responsible for around 6-10% of unwanted mortality among poultry flocks. Additionally, subclinical disease increases Feed Conversion Ratios and lowers performance. Accordingly, the economic consequences of this disease are considerable.

Various methods have been tried in an attempt to combat coccidiosis. Attempts have been made to control the disease through management strategies based on high standards of hygiene together with the use of chemical disinfectants in the environment of the poultry. However, even under extremely high hygienic conditions, it has not been found possible to eradicate coccidiosis although such measures were found to lower the initial infection pressure in a poultry house. Both live and attenuated vaccines have been investigated as methods of control, but these have only recently become available and are relatively expensive.

At present, coccidiosis in poultry is routinely controlled by the use of preventive anticoccidial drug programmes. Such programmes attempt to restrict coccidial infections thus limiting the effects of subclinical outbreaks of disease. This is usually accomplished by the continuous inclusion of anticoccidial agents in the feed from early in the life of the flock until close to slaughter for broiler birds or by controlled withdrawal for layers. When first developed, such agents were used individually. This often resulted in strains of parasites developing drug-resistance. It is presently attempted to control coccidiosis by the continual introduction of new drugs or by the use of drug programmes involving rotational use of anticoccidial agents of different biochemical structures either during the grow-out period (shuttle programmes) or at frequent intervals (rotation programmes). In spite of the routine use of anticoccidial agents in poultry feeds, subclinical coccidiosis is still found on the majority of poultry farms. Further the use of anticoccidial drugs adds significantly to the costs of poultry production. It would be an advantage if the amounts of such anticoccidial agents which presently have to be included in feeds to control coccidiosis could be reduced, or even eliminated entirely.

Accordingly, one object of the present invention is to provide a fresh class of compounds which can be used for the treatment and/or prophylaxis of coccidiosis.

Accordingly, the present invention provides the use of an enzyme selected from a carbohydrase and/or a protease for the manufacture of an agent for the treatment and/or prophylaxis of coccidiosis.

It has most surprisingly been found that the inclusion of a carbohydrase and/or a protease in the diet of an animal has the effect of treating or preventing coccidiosis. If such an enzyme is included in the diet of an animal, then the amounts of anticoccidial drugs which have previously been routinely incorporated in its diet can be reduced or in some cases omitted entirely. This enables considerable economic savings to be achieved in view of the relative expense of anticoccidial drugs.

When omitting anticoccidial drugs from an animal's diet, there are several potential further benefits. Thus, it has previously been necessary to withdraw anticoccidial drugs from the animal's diet for a certain period of time prior to slaughter. This ensures that the meat is relatively free from such drugs and so fit for

human consumption. In contrast, if anticoccidial drugs are omitted entirely from the animal's normal diet, as may be achieved in accordance with the present invention, then the animal can be slaughtered at any age rather than after a certain withdrawal period. This gives the farmer improved flexibility, and removes the risk of poultry becoming infected shortly prior to slaughter. Further, anticoccidial drug-residue free meat and eggs can be guaranteed. Such meat and eggs have a market advantage as compared to products which cannot support such a guarantee.

Even if the enzyme added to the animal's diet only enables the amount of anticoccidial drugs to be reduced, then the overall cost of controlling coccidiosis will be reduced. Synergy or potentiation may extend the useful life of the anticoccidial drug.

In a further aspect of the present invention, one or more of a carbohydrase and/or a protease may be included in the diet of an animal together with a conventional concentration of anticoccidial drugs. It has been found that this combination gives rise to a particularly advantageous synergy in that the resulting anticoccidial effect is greater than the mere addition of the individual effects of the enzyme(s) and anticoccidial drugs used separately.

The enzyme can be formulated as a pre-mix together with any other enzymes to be included in the feed. The pre-mix can be added to the raw materials before feed manufacture, during feed manufacture or as a final step once the feed is otherwise ready for use. It is also possible to add the enzyme directly as a liquid to a feed material preformed as pellets or as a mash.

It is also possible to include the enzyme in the animal's diet by incorporating it into a second (and different) feed or drinking water which the animal also has access to. Accordingly, it is not essential that the enzyme is incorporated into the feed itself, although such incorporation forms a particularly preferred aspect of the present invention.

If the enzyme is incorporated into the feed, then this preferably comprises at least 25% by weight of a cereal, and more preferably at least 35% by weight of the cereal. The cereal can be any one or more of wheat, rye, triticale, barley, oats, sorghum, rice and maize. It is particularly preferred that the cereal is wheat.

Although the cereal component of a cereal-based diet constitutes a source of protein, it is usually necessary to include sources of supplementary protein in the diet such as those derived from fishmeal, meatmeal or vegetables. These sources of supplementary protein can constitute up to 50% by weight of the animal feed. Sources of vegetable proteins include at least one of full fat soybeans, rapeseed, canola, soybean meal, rapeseed meal and canola meal.

If the enzyme is incorporated into the feed, then this is preferably done in a relative amount of 0.00001-10 g of the enzyme protein per kilo of the feed; more preferably 0.0001-1 g/kg; and most preferably 0.001-0.1 g/kg.

In the case that the enzyme used is a carbohydrase, then this is preferably a polysaccharidase such as a xylanase, a cellulase, an α -amylase or a pectinase. A preferred cellulase is β -glucanase.

If the polysaccharidase is a xylanase, then this may be obtained from a fungal source such as *Trichoderma*, *Aspergillus*, *Humicola* or *Neocallimastix*. It is particularly preferred that the xylanase is the low pl xylanase and/or the high pl xylanase obtainable from *Trichoderma longibrachiatum* such as described in WO 92/06209. Alternatively, the xylanase can also be obtained from a bacterium such as *Bacillus*, *Streptomyces*, *Clostridium* or *Ruminococcus*. It is also possible that the xylanase may be obtained from a host which has been subjected to genetic manipulation such as by the inclusion of an appropriate gene within a host bacterial or fungal strain.

In the case that the enzyme used is a protease, then this may be a subtilisin derived from the genus *Bacillus*. Such subtilisins are for example described in detail in US-A-4760025.

According to one preferred aspect of the present invention, the therapeutic agent does not include any non-enzymic anticoccidial agent. However, if such an agent is present, for instance to counter an outbreak of coccidiosis, then a conventional anticoccidial agent such as salinomycin, monensin, narasin, lasalocid, nicarbazin, maduramycin, nicarbazin and narasin in combination, diclazuril, dinitolmide, halofuginone, robenidine, amprolium or clodipol can be used. Such non-enzymic anticoccidial agents can be included in an animal feed preferably in an amount of 0-100 ppm, and more preferably 0-50 ppm. The latter amount in particular is well below the normal amounts of 50-200 ppm used for the majority of anticoccidial agents included in animal feeds.

This provides one of the advantages of the present invention of economic savings resulting from the use of lower amounts than is conventional of such relatively costly anticoccidial agents.

As mentioned above, it is preferred that the agent provided by the present invention is in the form of an animal feed. A suitable feed can be obtained by preparing a pre-mix of the carbohydrase and/or protease on a cereal carrier, and then adding an appropriate amount, e.g. 1 part by weight, of this pre-mix to 1000

parts by weight of a conventional animal feed.

Coccidiosis can be treated or prevented in accordance with the present invention in a variety of livestock. Thus, the enzyme of the present invention can be provided in the form of an agent, such as an animal feed, to livestock such as chicken, turkeys, geese, ducks, pigs, sheep or cattle. It is however particularly preferred that the agent is administered to broiler chickens.

The present invention is further explained by way of the following Examples.

Example 1

Four separate groups (A-D), each consisting of ten female Lohmann Brown chicks, were fed the following maize/wheat-based diet for their first twelve days of life:

Maize/wheat-based diet	
Wheat	25% by weight
Maize	42% by weight
Soybean meal	20% by weight
Fishmeal	10% by weight
Vitamin and Mineral Mixture	3% by weight

Each of the groups were then fed the following wheat-based diet for the days 13-21:

Wheat-based diet	
Wheat	67% by weight
Soybean meal	20% by weight
Fishmeal	10% by weight
Vitamin and Mineral mixture	3% by weight

The diet of the chicks in the groups C and D was supplemented by an enzyme mix including xylanase obtained from *Trichoderma Longibrachiatum* and β -glucanase also obtained from *Trichoderma Longibrachiatum*. Thus, a pre-mix containing crude xylanase and crude β -glucanase was prepared and coated on a cereal carrier. This was then added to the above wheat-based feed such that the resulting feeds comprised about 0.0025 g of xylanase protein and about 0.005 g of β -glucanase protein per kg of feed. The diets fed to the chicks in groups A and B were not supplemented with enzymes.

The chicks in groups B and D were infected with oocysts on day 14. This infection took the form of 5000 *E. tenella* and 50000 *E. acervulina* oocysts per chick. The chicks in groups A and C were not infected.

On day 21, seven days after infection, the chicks were killed and body weight gain and lesion scoring according to the Johnson and Reid system (Exp. Parasitol. (1970) Vol. 28, pp 30-36) in both the duodenum and caecae were undertaken. The results obtained are set out in the following Table 1:

Table 1

Group	Enzyme	Infection	Average Body Weight gain (g)	Lesion Score
A	-	-	89.2	0.00
B	-	+	42.4	3.78
C	+	-	91.4	0.00
D	+	+	63.5	3.00

It can be understood from the above results that coccidial infection in the group B leads to a significant loss in average body weight gain and a disadvantageous increase in lesions as compared to the control group A. On the other hand, it is clear that when the wheat-based diet of the chicks is supplemented by enzymes in the case of group D, then the effects of coccidial infection are markedly reduced. In particular,

the average body weight gain for the chicks in group D is significantly greater than for the chicks in group B. Further, the lesion score for the chicks in group D was lower than the lesion score for the chicks in group B.

5 Example 2

Four groups (E-H), each consisting of twenty Ross male broiler chicks were fed the wheat-based diet set out in the above Example 1 for their first twenty-eight days. The diets of the chicks in groups F and H were supplemented with xylanase obtained from *Trichoderma Longibrachiatum*. Thus a pre-mix containing
10 crude xylanase was prepared and coated on a cereal carrier. This was then added to the above wheat-based feed such that the resulting feeds comprised about 0.0025 g of xylanase protein per kg of feed. The diets fed to the chicks in groups E and G were not supplemented with xylanase.

The chicks in groups G and H were infected with oocysts on day 14 in the same manner as the groups B and D were infected in the above Example 1.

15 On day 21, seven days after the infection was introduced, the average body weight gain, average feed intake and feed conversion ratio of the chicks in each group were measured. In addition, 10 chicks from each group were killed and their intestinal viscosity measured. These chicks were also subjected to lesion scoring according to the Johnson and Reid system in both the duodenum and caecae. The results are set out in Table 2 below:

20 Table 2

25	Group	Enzyme	Infection	Average Body Weight Gain (g)	Average Feed Intake (g)	Feed conversion Ratio	Lesion Score	Viscosity (Pa.s)
	E	-	-	318	670	2.11	0	0.0184
	F	+	-	347	670	1.93	0	0.00625
30	G	-	+	242	610	2.52	1.9	0.00607
	H	+	+	244	500	2.05	2	0.00266

35 The ten remaining chicks in each of the groups E-H were fed for a further seven days, that is for a period ending 14 days after infection. These chicks were then assessed for their average body weight gain, average feed intake and feed conversion ratio. The results obtained are set out in the following Table 3:

Table 3

40	Group	Enzyme	Infection	Average Body Weight Gain (g)	Average Feed Intake (g)	Feed Conversion Ratio
	E	-	-	430	920	2.14
	F	+	-	426	880	2.06
45	G	-	+	396	740	1.87
	H	+	+	467	940	2.01

50 The results set out in Table 2 above indicate that average body weight gain was significantly depressed by coccidial infection with or without enzyme supplementation. On the other hand, the body weight gain for the chicks in group H picked up markedly in the period 7-14 days after infection as can be seen from the results in Table 3.

55 From these Tables, it is also clear that there is a negative effect on the feed conversion ratio (FCR) due to coccidial infection. It should be mentioned that the FCR of a feed is the ratio of the amount of feed consumed relative to the weight gain of the animal. A low FCR indicates that a given amount of feed results in a growing animal gaining proportionately more weight. This means that the animal is able to utilise the feed more efficiently. Enzyme addition numerically has a significant impact on the FCR results in Table 2.

Thus, the FCR is improved by about 19% in the case of infected birds whose diets are supplemented by the enzymes. In comparison, for birds which are not infected, the FCR of the chicks whose diets are supplemented by enzymes improves only by 8.5% compared to the chicks in the group whose diets are not so supplemented.

Turning to the results set out in Table 3, it will be seen that body weight gain was substantially increased by enzyme addition in the infected group H as compared to the group G which were not provided with enzyme supplements. This is a most unexpected but advantageous finding. In contrast, it can be seen by comparing the results for groups E and F in Table 3 that the addition of enzyme in the absence of infection has no significant effect.

The FCR data set out in Table 3 apparently shows the best value for the group G. However, this is misleading because the chicks in this group grow so slowly that they will not meet the required end body weight after the usual growing period, and the economic loss caused by this offsets any advantage in improved feed conversion.

Example 3

Ross male broilers were fed the wheat-based feed set out in the above Example 1 for their first 12 days. At Day 12, the birds were randomised by weight into eight groups each containing 20 broilers. These eight groups "I"- "L" were provided with feeds in accordance with the following Table 4:

Table 4

Group	Feed
I-	Wheat alone
J-	Wheat + 5 ppm of Cygro
K-	Wheat + enzyme
L-	Wheat + enzyme + 5 ppm of Cygro
I+	Wheat alone
J+	Wheat + 5 ppm of Cygro
K+	Wheat + enzyme
L+	Wheat + enzyme + 5 ppm of Cygro

In the above Table 4, the feed provided to Group I is the initial wheat-based feed. The feeds provided to Groups J and L are each supplemented with 5 ppm of Maduramycin (the recommended level of inclusion) which is an anti-coccidial ionophore marketed as Cygro by Cyanamid. The enzyme which is included in each of the feeds provided to Groups K and L is a xylanase obtained from *Trichoderma longibrachiatum*. This is added as a pre-mix, which contains 0.375% of xylanase protein, to the feed in an amount of 0.6 g of the pre-mix per kg of the feed.

At Day 14, the four "+" groups were orally infected with 50,000 oocysts of *E. acervulina* and 5,000 oocysts of *E. tenella*. Feed conversion ratios (for some groups) and lesion scores were measured. The results for the measurement of the feed conversion ratios during the trial are set out in the following Table 5:

Table 5

Group	Day 0 to 7	Days 7 to 14	Days 0 to 14
I-	2.27	2.85	2.49
K-	2.49	2.94	2.67
I+	2.63	2.48	2.56
K+	2.51	2.11	2.50

From the above results, it will be seen that the inclusion of the enzyme in the feed provided to Group K+ improved the feed conversion ratio over the critical 7 day period following infection compared to Group I+ fed the unsupplemented wheat diet. This effect was sustained throughout the duration of the trial.

Seven days after infection, 10 birds from each group were killed and examined for lesions caused by *E. acervulina* and *E. tenella* according to the method of Johnson & Reid. The results obtained are set out in the following Table 6:

Table 6

Group	<i>E. acervulina</i>	<i>E. tenella</i>
I-	0	0
J-	0	0
K-	0	0
L-	0	0
I+	2.5	2.6
J+	2.2	2.2
K+	2.1	2.8
L+	2.0	1.7

From the results set out above, it can be seen that lesion scores for *E. acervulina* were significantly lower for groups whose feeds were supplemented with the enzyme as compared to the closest comparable control groups. The inclusion of the enzyme in the feeds improved the lesion scores and also gave rise to a further improvement when used in combination with the anti-coccidial agent. The lesion scores caused by *E. tenella* did not improve on enzyme supplementation alone compared to the unsupplemented wheat diet. On the other hand, the presence of the enzyme did significantly improve the performance of the anti-coccidial agent as can be seen from a comparison between Groups J+ and L+.

Example 4

Ross male broilers were fed the wheat-based feed set out in the above Example 1 for their first 12 days. At Day 12, the birds were randomized by weight into two groups each containing 66 broilers. These two Groups "M" and "N" were provided with feeds as follows.

The feed of Group N was the initial wheat-based diet without any supplementation. The feed of Group M was the same feed supplemented with a xylanase enzyme obtained from *Trichoderma longibrachiatum*. This enzyme was added as a pre-mix containing 0.187 % of xylanase protein to the feed in an amount of 1 g of the pre-mix per kg of the feed. The pre-mix also included a protease obtained from *Bacillus* sp. This is present in the pre-mix in an amount of 0.06% of protease protein.

At Day 14, the two groups were orally infected with 30,000 oocysts of *E. acervulina*, 15,000 oocysts of *E. maxima* and 3,000 oocysts of *E. tenella*. Seven days after infection, birds from each group were killed and examined for lesions caused by *E. acervulina*, *E. maxima* and *E. tenella* according to the method of Johnson & Reid. The results obtained are illustrated in the following Table 7:

Table 7

Diet	Lesion Score <i>E. acervulina</i>	Lesion Score <i>E. maxima</i>	Lesion Score <i>E. tenella</i>
Group N	1.8	0.8	2.5
Group M	1.8	0.6	1.7

From these results, it can be seen that lesion scores were reduced in Group M fed the enzyme supplemented feed in the case of lesions caused by both *E. maxima* and *E. tenella*.

The effect demonstrated above of treating coccidiosis in the case of wheat-based diets can also be obtained in feeds based on rye, triticale, barley, oats, sorghum, rice or maize. Further, similar results can be obtained when feeds incorporating enzyme supplementation in accordance with the present invention are fed to other animals infected or infectable by coccidiosis such as turkeys, geese, ducks, pigs, sheep and cattle.

Claims

1. Use of an enzyme selected from a carbohydrase and/or a protease for the manufacture of an agent for the treatment and/or prophylaxis of coccidiosis.
2. Use according to claim 1, wherein the agent is in the form of an animal feed.
3. Use according to claim 2, wherein the animal feed comprises at least 35% by weight of the cereal.
4. Use according to claim 3, wherein the cereal is wheat.
5. Use according to any of claims 2-4, wherein the feed further comprises fishmeal, meatmeal or a vegetable protein as a supplemental source of protein.
6. Use according to any of claims 2-5, wherein the animal feed comprises 0.00001-10 g/kg of the enzyme protein.
7. Use according to any preceding claim, wherein the carbohydrase is one or more polysaccharidases.
8. Use according to claim 7, wherein the polysaccharidase is a xylanase, a cellulase, an α -amylase or a pectinase.
9. Use according to any preceding claim, wherein the agent further comprises a non-enzymic anti-coccidial agent.
10. Use according to claim 9, wherein the non-enzymic anticoccidial agent is salinomycin, monensin, narasin, lasalocid, nīcarbazine, nicarbazin and narasin in combination, diclazuril, dinitolmide, halofuginone, robenidine, maduramycin, amprolium or clopidol.